Pesticide Safety among Farmworkers: Perceived Risk and Perceived Control as Factors Reflecting Environmental Justice

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Farmworkers in the United States constitute a population at risk for serious environmental and occupational illness and injury as well as health disparities typically associated with poverty. Pesticides are a major source of occupational injury and illness to which farmworkers are exposed. Efforts to provide safety training for farmworkers have not been fully evaluated. Based on the Health Belief Model, this analysis examines how safety information affects perceived pesticide safety risk and control among farmworkers and how perceived risk and control affect farmworker knowledge and safety behavior. Data are based on interviews conducted in 1999 with 293 farmworkers in eastern North Carolina as part of the Preventing Agricultural Chemical Exposure in North Carolina Farmworkers' Project. Perceived pesticide risk and perceived pesticide control scales were developed from interview items. Analysis of the items and scales showed that farmworkers had fairly high levels of perceived risk from pesticides and perceived control of pesticide safety. Receiving information about pesticide safety (e.g., warning signs) reduced perceived risk and increased perceived control. Pesticide exposure knowledge was strongly related to perceived risk. However, perceived risk had a limited relationship to safety knowledge and was not related to safety behavior. Perceived control was not related to pesticide exposure knowledge, but was strongly related to safety knowledge and safety behavior. A key tenet of environmental justice is that communities must have control over their environment. These results argue that for pesticide safety education to be effective, it must address issues of farmworker control in implementing workplace pesticide safety. *Key words*: environmental justice, health disparities, migrant farmworkers, participatory research, pesticide. *Environ Health Perspect* 110(suppl 2):233–240 (2002). *http://ehpnet1.niehs.nih.gov/docs/2002/suppl-2/233-240arcury/abstract.html*

The estimated 4.2 million migrant and seasonal farmworkers in the United States constitute a population at risk for serious environmental and occupational illness and injury as well as health disparities typically associated with poverty (*1–7*). Although farmworkers are essential to the production of food in the United States, they have little power to control their work conditions. Farmworkers often make little more than minimum wage, seldom receive any employment benefits, and in many areas are not organized. Most farmworkers are immigrants to the United States. The national farmworker population has become increasingly Latino and Mexican during the past decade (*8–10*). In 1998, 81% of all migrant and seasonal farmworkers in the United States were foreign-born, and 95% of those were born in Mexico (*10*).

Although some areas of the United States (e.g., California, Florida) have routinely employed large numbers of Latino seasonal and migrant farmworkers, other areas have recently experienced a dramatic increase in these workers as family labor gives way to hired labor. In North Carolina, which ranks fifth in the size of its farmworker population, most farmworkers 15 years ago were African American. Today only 10% are African American; most, like the rest of the U.S. farmworker population, are Latino (*8–10*).

Pesticides are a major source of occupational injury and illness to which farmworkers are exposed. Contemporary U.S. agriculture uses large amounts of pesticides (*11,12*). Agricultural pesticides include those chemicals intended to kill insects, plants, fungi, rodents, and other organisms that interfere with the production, storage, and distribution of agricultural produce. Most agricultural pesticides now being used can have detrimental effects on human health (*13*). The nature of farm work exposes everyone who works on a farm to pesticides—farm owners and managers as well as farmworkers. However, farmworker pesticide exposure must be considered separately because of the extensive hand labor that most farmworkers perform and because farmworkers have limited power to influence workplace safety. The health effects of pesticide exposure can be immediate and include rashes, headaches, nausea and vomiting, disorientation, shock, respiratory failure, coma, and, in severe cases, death (*13–15*). Pesticide exposure can also have long-term effects on health in the form of cancer and neurologic and reproductive problems (*16–21*).

Efforts to provide safety training for farmworkers have not been fully evaluated. The most comprehensive pesticide safety regulations for all agricultural workers are the U.S. Environmental Protection Agency's Worker Protection Standard (*22*). The two national evaluations of these regulations have not included any direct data collection with farmworkers (*23,24*). Several studies have questioned the implementation of these regulations [e.g., Arcury et al. (*9,25*)]. The U.S. Government Accounting Office has issued a report critical of the implementation of the Worker Protection Standard (*26*).

There are important questions about the cultural and educational appropriateness of the regulations and the materials developed to implement them. In general these materials are prescriptive, telling farmworkers how to behave, but they fail to tell how such behaviors will reduce risk (*27*).

A variety of theories have been developed to provide frameworks for understanding and predicting change in health behaviors (*28*). The Health Belief Model (HBM) (*29*) is particularly useful for the study of farmworker pesticide safety behavior because of its simplicity and parsimony. It sees behavior as a function of a person's subjective value of an outcome and his/her expectation that a particular health behavior will result in that outcome. The HBM has six key concepts. *Perceived susceptibility* is an individual's belief that he/she is at risk of an outcome. The relationship of perceived susceptibility to taking a health action is modified by *perceived severity* of the outcome, the *perceived benefits* of a health behavior to modify the risk of the outcome, and the *perceived barriers* to taking action. Beyond these, *cues to action* and *self-efficacy* can also modify the relationship of perceived susceptibility to action. Cues to action include recognized symptoms, knowledge, and education. Self-efficacy is the confidence in one's ability to reduce risk through behavior change. Most of the work to date on farmworkers has addressed the constructs of perceived risk and perceived control/self-efficacy without linking it to knowledge.

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Several studies have addressed farmworker knowledge, beliefs, and perceptions about pesticide exposure risk. Baer and Penzell (*30*) found that Latino migrant farmworkers in Florida interpreted pesticide exposure-related symptoms within a cultural framework, attributing residual symptoms of pesticide poisoning to the Mexican folk illness *susto*. Lantz et al. (*31*) used focus group data to examine Latino farmworker perceptions of pesticide exposure and their beliefs about cancer causation. They found that farmworkers knew that pesticide exposure could cause health problems but did not link pesticide exposure to cancer.

Quandt et al. (*32*) present the most developed analysis of farmworker perceptions of pesticide exposure. Their analysis of in-depth interview data collected with farmworkers in eastern North Carolina found several major themes that reflect farmworker pesticide exposure beliefs. One is the belief that susceptibility to the effects of chemicals is highly individualized; some persons are sensitive and experience ill effects, and others are inherently more resistant. Another theme indicates that most farmworkers are concerned with the immediate or acute effects of exposure. Very few are aware of potential long-term consequences of exposure to pesticides, and none of them link these to chronic exposure or to residues. A final theme indicates that farmworkers are divided on whether pesticides are potentially dangerous. Some farmworkers believe that pesticides are not dangerous to humans, and that farmers would not use chemicals if they could harm humans. Others contend that farmers have no regard for their health. Quandt et al. conclude that the cognitive model of susceptibility varies among farmworkers and that it contradicts the epidemiologic and toxicologic models of pesticide effects. Elmore and Arcury (*33*) build on the analysis of Quandt et al., examining the pesticide exposure and health beliefs among farmworkers in western North Carolina. Their qualitative results largely substantiate Quandt's earlier work; most of the farmworkers they interviewed knew that pesticides could be harmful, but the workers varied in their levels of knowledge regarding routes of exposure, specific health effects of pesticides, and ways to avoid and reduce exposure. They conclude that a perceived lack of control among farmworkers and health beliefs were salient factors that decreased workers' use of safety practices. A study of southern Mexican farmworker beliefs about pesticide exposure (*34*) found a belief system similar to that described by Quandt et al. (*32*). For example, the Mexican farmworkers were most concerned about acute effects, not residues.

In terms of perceived control, Grieshop et al. (*35*) found that California farmworkers attributed more control over workplace safety to factors outside of themselves (e.g., in God, luck, or supervisors) than to factors they could control. Although they thought about ways to stay safe in the workplace, they also had a cognitive strategy of accepting danger. Vaughan (*36,37*) also found that many California farmworkers perceived little control over exposure to chemicals and their negative health effects, and this was associated with failure to use protective behaviors to prevent or reduce exposure. Those farmworkers in better economic circumstances were more likely to perceive themselves as having control over exposure (*38*).

Analysis by Austin et al. (*39*) of 1998 data from eastern North Carolina farmworkers also shows that control is a significant issue for pesticide safety. Farmworkers perceive many preventive measures to be outside their control. The ability of farmworkers to engage in safe practices depended upon their ability to communicate with their employer, power relationships at work, and the availability of protective equipment. Unlike Vaughan (*38*), having greater information and training did not predict a greater sense of control in the North Carolina study.

Using questionnaire data from farmworkers in North Carolina, in this article we examine four questions about farmworker perceived pesticide safety risk and perceived pesticide safety control. First, what is the level of perceived pesticide risk (PPR) among these farmworkers? Second, what is the level of perceived pesticide control (PPC) among these farmworkers? Third, what background characteristics and pesticide information factors are related to PPR and PPC among these farmworkers? Finally, how are PPR and PPC related to knowledge of pesticide exposure sources, knowledge of pesticide safety behaviors, and actual safety actions among farmworkers?

Methods

Data Collection

Our data were collected as part of the PACE (Preventing Agricultural Chemical Exposure among North Carolina Farmworkers) project. PACE was a community-based participatory research project designed to reduce farmworker pesticide exposure by developing, implementing, and disseminating a culturally appropriate safety education program (*40,41*). The North Carolina Farmworkers' Project, a community-based farmworker advocacy organization, was a partner in PACE, participating in all research and intervention activities. The PACE project was based in an eight-county region of eastern North Carolina with the state's highest concentrations of farmworkers. Most farms in North Carolina employ 10 or fewer workers (*42*). The PACE project targeted farms that produced tobacco or cucumbers, as these crops involve considerable hand labor. The focus of PACE was the development of safety education programs for field workers, rather than pesticide handlers or licensed applicators. Pesticide regulations for field workers in North Carolina are taken directly from the U.S. Environmental Protection Agency's Worker Protection Standard (*22*).

Data for this analysis came from preintervention interviews conducted with 293 Latino farmworkers during June and July 1999. There was no available sampling frame of farmworkers in North Carolina. We therefore implemented a two-stage procedure to locate and recruit participants (*9,25*), on the basis of the need to maximize the representativeness of the sample, while taking into account the exigencies of working with a largely undocumented, relatively invisible, and highly mobile population. We knew that workers could be located in a variety of residential sites, including on-farm labor camps, trailer parks, old farm houses, and apartments. The first stage of the sampling plan was intended to maximize representativeness of the sample by selecting a broad range of sites. A site was defined as a residential locale in which all or most residents were farmworkers and their families. Community representatives created a list of potential sites on the basis of their knowledge as area residents, by community reconnaissance, by interviewing farmers, and by talking with farmworker service providers. Each site was visited to ascertain whether the farmworkers present would be willing to participate in the study, if asked. Community members were hired and accompanied the project staff on site visits. The PACE staff then selected a mix of sites from those visited, including large and small labor camps, trailer parks, and rental housing.

Thirty-six sites were included in the first stage of the sample. One site originally selected for the study was dropped and replaced when the farmer who owned the site refused to have his employees participate. In the second sampling stage, farmworkers were recruited at each site. All site residents were asked to participate in the 33 sites with fewer than 10 resident workers. In the other three sites, the interview team leader identified workers to be interviewed by first selecting any women present, then selecting a range of ages from those present to achieve a total of 10 workers per site. Because relatively few women work as farmworkers in North Carolina, this procedure was designed to maximize the number of women in the sample. Using this system of multiple contacts leading up to recruitment familiarized farmworkers with the project; there were very few refusals at the stage of actual recruitment.

The interview questionnaire was developed in English and Spanish. Items were taken from existing instruments whenever possible. In particular, items used in the construction of the scales used to measure PPR and perceived pesticide safety control are based on items developed by Vaughan (*36*). Dr. Vaughan graciously assisted our efforts by sharing copies of her original data collection instruments with us. A professional service translated items into Spanish; these items were edited by native Spanish speakers. The entire questionnaire was pretested with farmworkers residing in the study area.

Interviewers were fluent in Spanish. All attended two 3-hr training sessions and conducted practice interviews. Interview teams included a PACE staff supervisor, a college student fluent in Spanish, and one or more former farmworkers. Interview questionnaires were checked on site by the PACE staff supervisor, and any discrepancies were resolved. Interviews were completed in approximately 25 min. Participants were given information about the study and the interview and were asked for consent. At the end of the interview participants were given a tee shirt printed with a safety message. No mention was made of the incentives before the interview to ensure that they were not inducements to participate. The protocol for this study was approved by the Institutional Review Boards of the University of North Carolina at Chapel Hill (Chapel Hill, North Carolina) and the Wake Forest University School of Medicine (Winston-Salem, North Carolina).

Measurement

The two central variables for this analysis are perceived risk of pesticide health effects and perceived control over the harmful effects of pesticide exposure. Measurement of each variable is based on a scale developed from items included in the survey questionnaire.

The PPR scale was based on five consecutive questionnaire items. These items asked: *a*) How do you believe that your health is hurt by pesticides? *b*) Do you believe that the health of other farmworkers is hurt by pesticides? *c*) Do you believe that the health of the children of farmworkers is hurt by pesticides? *d*) Do you believe that health of unborn children of farmworkers is hurt by pesticides? and *e*) Do you believe that the ability of farmworkers to have children is hurt by pesticides? The response categories for each item were (1) not at all, (2) not enough to cause concern, (3) enough to cause a little concern, and (4) enough to worry a great deal. Responses to these items were summed. Respondents who did not complete all five items were dropped from the analysis of this scale, decreasing the sample size from 293 to 283. The scale had a range of 5 to 20, where 5 indicated the least perceived risk and 20 indicated the greatest perceived risk. The mean for this scale was 14.55, with a standard deviation of 4.02. Cronbach's Alpha for this PPR scale was 0.85.

The PPC scale was based on four consecutive questionnaire items. These items asked: *a*) How much control do you believe you have over avoiding any possible harmful health effects of pesticides? *b*) How much control do you believe you have over wearing clothes that will protect you from the harmful health effects of pesticides? *c*) How much control do you believe you have over washing your hands in the fields while you are working? and *d*) How much control do you believe you have over washing your clothes after each time you work in them? The response categories for each item were (1) no control, (2) a small amount of control, (3) a moderate amount of control, and (4) great deal of control. Responses to these items were summed. Respondents who did not complete all four items were dropped from the analysis of this scale, decreasing the sample size from 293 to 289. The resulting scale had a range of 4 to 16, where 4 indicated the least perceived control and 16 indicated the greatest perceived control. The scale mean was 11.61, with a standard deviation of 2.85. Cronbach's Alpha for this PPC scale was 0.72.

The PPR scale and the PPC scale measured independent dimensions of perceived pesticide safety. The Pearson correlation coefficient for the two scales was –0.02 ($p = 0.7602$).

Measures were developed for two other sets of variables: farmworker characteristics (including pesticide safety knowledge) that might affect the levels of PPR and PPC, and measures of pesticide safety behavior that might be affected by PPR and PPC.

Characteristics that might affect PPR and PPC include background characteristics and safety information provided to farmworkers. Although information on farmworker gender and ethnicity was collected, these characteristics are not considered in the analysis, as there was little variability in either. Farmworker age (AGE) was measured in years. The number of years worked in agriculture in the United States (WORKUS) was collected as the actual number of years. Ability to understand English (ENGUNDER) had the values none or very little. Moving from place to place for work (MIGRATE), in the United States on a work contract (CONTRACT), and having lived or living in housing on the farm where one works (HOUSING) were dichotomous variables.

Six measures of sources of pesticide safety information were included in the questionnaire. Having ever received pesticide safety information or training (TREVER) and having received pesticide safety information or training this year (TRYEAR) were dichotomous variables. Participants stating that they were told when pesticides were applied (PESTTOLD), that they knew the names of applied pesticides (PESTNAME), that pesticide information was posted where it could be seen (PESTSIGN), and that pesticide restricted-entry interval signs were posted (SIGNID) were also dichotomous variables. (A restricted-entry interval is the period of hours or days before a person can enter an area to which pesticides have been applied without wearing specific personal protective equipment.)

We examined three sets of variables that are measures of pesticide exposure knowledge, pesticide safety knowledge, and pesticide safety behaviors. Measures of pesticide exposure knowledge included exposure at work and at home. Eight dichotomous items (EXWORK1 through EXWORK8) asked participants if different sources exposed them to pesticides while working. Examples of these sources included "breathing pesticides in the air," "being sprayed," and "from residues on equipment." Another eight dichotomous items (EXHOME1 through EXHOME8) asked participants if different sources exposed them to pesticides at home. Examples of these behaviors included "bringing home pesticides from work," "not changing clothes after coming home," and "not bathing or showering when getting home."

Knowledge of pesticide safety behaviors was measured with four sets of dichotomous items. Participants were asked how they should dress to reduce the harmful effects of pesticides. They were then scored for each of seven possible responses, such as "wear a shirt with long sleeves" and "wear a hat." Participants were asked when they should wash their hands to reduce the harmful effects of pesticides. They were then scored for each of two possible responses: "before eating," and "before going to the bathroom." Participants were asked when they should shower to reduce the harmful effects of pesticides. They were then scored for each of two possible responses: "immediately after work," and "after direct contact with a pesticide." Finally, participants were asked how they should care for their clothes to reduce the harmful effects of pesticides. They were then scored for each of two possible responses: "launder work clothes separately," and "wear clean work clothes daily."

Participants were first asked to respond to a general measure of pesticide safety behavior: “Do you use methods to protect yourself from pesticide exposure?” (PROTUSE). This had the response categories of “never,” “sometimes,” “frequently,” and “always.” Participants were then read a list of 13 safety behaviors and asked the number of days in the previous work week they followed that safety behavior. Number of days the safety behavior was followed was adjusted for the actual number of days worked (e.g., if worked 2 days and used the behavior 1 day, score of 0.5; if worked 6 days and used the behavior 3 days, score of 0.5).

Table 1. Background characteristics of study participants.

Background characteristics	*n*	%
Gender		
Male	273	93.2
Female	20	6.8
Ethnicity		
Mexican	276	94.2
Other Latino	17	5.8
Age (years)		
<20	33	11.3
20–24	75	25.6
25–29	62	21.2
30–34	35	11.9
35+	88	30.0
Understand English		
None	121	41.4
Some	171	58.6
Years worked in U.S. agriculture		
1–2	173	59.9
3–4	53	18.3
5+	63	21.8
Migrant		
No	103	35.2
Yes	188	64.2
Live in housing on farm where works		
No	85	29.3
Yes	205	70.7
Labor contract		
No	155	53.1
Yes	137	46.9

Analysis

Descriptive statistics, including frequencies and percentages, were generated for the demographic measures. The PPR and PPC scales were treated as continuous measures for statistical analyses. Correlation analyses, including Cronbach’s Alpha, were completed to assess the relationship for continuous measures; Pearson’s correlation coefficient was used as a measure of association between such measures. For dichotomous variables, associations with PPR and PPC scales were analyzed using independent *t*-tests.

Results

Respondent Characteristics

The farmworkers who participated in our study were overwhelmingly male and from Mexico (Table 1). They were young, with almost 60% being under 30 years of age. Almost 60% had worked in U.S. agriculture for 2 years or less. Two-fifths stated that they understood no English, with the others indicating that they understood very little English. Most considered themselves to be migrants. More than two-thirds lived in housing on the farms where they were working. Almost half of these workers stated that they were in the United States on a labor contract.

Perceived Risk and Perceived Control

About 20–30% of the workers did not perceive pesticides to be enough of a risk to themselves, other farmworkers, or their children to cause concern (Table 2). About equal percentages (22%) felt that there was not much concern about their health or the health of other farmworkers being hurt by pesticides. There was less concern expressed over the risk of pesticides hurting farmworker children, with 26% indicating that this was of little or no concern. About 28% of the respondents had little or no concern about pesticides harming unborn children, and about the same percentage had little or no concern about pesticides affecting their ability to have children. The mean value for entire PPR scale was 14.55.

Few of the farmworkers felt that they had a great deal of control over reducing their exposure to pesticides (Table 3). Fewer than 5% felt they had a great deal of control over wearing clothes that protect them from pesticides and of washing their working clothes each time they wore them. Conversely, 37.1 and 54.1%, respectively, reported having no control over these two behaviors. More of the farmworkers felt they had a great deal of control over avoiding the harmful effects of pesticides (11.7%) and of washing their hands in the fields while working (15.1%), but 22.4 and 35.6%, respectively, felt they had no control over these issues. A mean of 11.6 for the PPC scale shows that farmworkers are divided in their perceived level of control

Variability in Perceived Risk and Perceived Control

There was no relationship between the farmworker background characteristics, age, or ability to understand English and either PPR or PPC. Years worked in U.S. agriculture was also not related to either perceived risk ($r = 0.008$, $p = 0.8945$) or perceived control ($r = 0.079$, $p = 0.1814$). However, other migration and work status variables were related to PPR and PPC. Farmworkers who migrated for work or lived in housing on the farm where they worked had greater perceived risk (Table 4). Farmworkers with a work contract and who lived in housing on the farm where they worked had higher mean scores on the PPC (Table 5).

More important than the relationship of background, migration, and work status variables to perceived risk and perceived control were variables indicating access to pesticide

Table 2. Items included in the Perceived Pesticide Risk (PPR) scale: number and percent giving each response.

Scale items	Not at all *n* (%)	Not enough to cause concern *n* (%)	Enough to cause some concern *n* (%)	Enough to worry a great deal *n* (%)	Total *n* (%)
Believe your health is hurt by pesticides	34 (11.6)	35 (11.9)	114 (38.9)	110 (37.5)	293 (100.0)
Believe health of other farmworkers hurt by pesticides	34 (11.6)	31 (10.6)	127 (43.5)	100 (34.2)	292 (100.0)
Believe health of farmworkers’ children hurt by pesticides	49 (16.8)	29 (9.9)	122 (41.8)	92 (31.5)	292 (100.0)
Believe health of farmworkers’ unborn children hurt by pesticides	56 (19.2)	27 (9.3)	123 (42.3)	85 (29.2)	291 (100.0)
Believe farmworkers’ ability to have children hurt by pesticides	51 (17.9)	28 (9.8)	131 (46.0)	75 (26.3)	285 (100.0)

Table 3. Items included in the Perceived Pesticide Safety Control (PPC) scale: number and percent giving each response.

Scale items	No control *n* (%)	Small amount of control *n* (%)	Moderate amount of control *n* (%)	Great deal of control *n* (%)	Total *n* (%)
Avoiding possible harmful effects of pesticides	65 (22.4)	78 (26.9)	113 (39.0)	34 (11.7)	290 (100.0)
Wearing clothes that protect you from harmful effects of pesticides	108 (37.1)	77 (26.5)	92 (31.6)	14 (4.8)	291 (100.0)
Washing your hands in the fields while you are working	104 (35.6)	53 (18.2)	91 (31.2)	44 (15.1)	292 (100.0)
Washing your clothes each time you work in them	158 (54.1)	67 (22.9)	59 (20.2)	8 (2.7)	292 (100.0)

safety information. Increased access to pesticide safety information was associated with lower mean PPR scores. Those farmworkers who reported that they were told when pesticides were applied (although the statistical significance is only marginal), that they knew the names of the pesticides that were applied, and that pesticide information was posted where it could be seen had lower perceived risk (Table 4). Increased access to pesticide safety information was also associated with higher PPC scores. Those farmworkers who reported having ever received pesticide safety training or information, who reported having received pesticide information or training this year, that they were told when pesticides were applied, that pesticide information was posted where it could be seen, and that restricted-entry interval signs were posted where they worked had greater perceived control of pesticide safety (Table 5).

Effects of Pesticide Exposure Knowledge and Pesticide Safety Knowledge on PPR and PPC

Greater pesticide exposure knowledge was associated with higher PPR scores (Table 6). Those who stated that each of the eight work exposure items and each of the eight home exposure items were sources of pesticide exposure had significantly higher mean PPR scores. For example, those who stated they could be exposed from residues on equipment (EXWORK7) had a mean score of 15.20, compared with a mean score of 12.64 for those who disagreed with this statement. Those who stated they could be exposed by bringing pesticide containers home from work (EXHOME2) had a mean score of 15.15, compared with a mean score of 12.63 for those who disagreed with this statement. No significant association was found between any of the pesticide exposure knowledge items and PPC.

There was a limited relationship of knowledge of pesticide safety behaviors to PPR. Knowledge of three safety behaviors was significantly associated with PPR. Those who stated they could reduce their exposure to pesticides by washing their hands before going to the bathroom (WASHBATH: no = 14.07, yes = 15.37, p = 0.008), showering immediately after work (SHOWERWK: no = 12.57, yes = 14.79, p = 0.004), and laundering their work clothes separately from other clothes (LAUNSEP: no = 13.43, yes = 14.96, p = 0.004) had greater PPR scores.

Table 4. Comparison of mean summed scores for Perceived Pesticide Risk (PPR) scale, by worker characteristics and pesticide knowledge.

Variable	No *n*	No Mean (SD)	Yes *n*	Yes Mean (SD)	*t*	*p*
CONTRACT: in United States on work contract	147	14.65 (4.11)	135	14.42 (3.92)	0.47	0.64
MIGRATE: move place to place for work	100	13.60 (4.29)	181	15.08 (3.77)	–2.99	0.003
HOUSING: living in housing on farm	79	13.61 (3.76)	201	14.98 (4.05)	2.59	0.01
TREVER: ever received pesticide safety training or information	124	14.85 (3.75)	154	14.30 (4.22)	1.13	0.26
TRYEAR: this year received pesticide safety training or information	149	14.90 (3.78)	129	14.14 (4.26)	1.56	0.12
PESTTOLD: told when pesticides are applied	145	15.56 (3.63)	138	14.86 (4.36)	1.76	0.08
PESTNAME: know the names of applied pesticides	250	15.35 (3.85)	31	13.70 (4.63)	3.82	0.0002
PESTSIGN: pesticide information posted where it can be seen	178	14.95 (3.48)	104	13.88 (4.33)	2.18	0.03
SIGNID: restricted entry interval signs are posted	150	14.79 (3.59)	132	14.31 (4.47)	0.98	0.33

SD, standard deviation.

Table 5. Comparison of mean summed scores for Perceived Pesticide Safety Control (PPC) scale, by worker characteristics and pesticide knowledge.

Variable	No *n*	No Mean (SD)	Yes *n*	Yes Mean (SD)	*t*	*p*
CONTRACT: in United States on work contract	151	11.60 (2.93)	137	12.17 (2.66)	–3.15	0.002
MIGRATE: move place to place for work	99	11.25 (2.61)	188	11.81 (2.96)	–1.59	0.11
HOUSING: living in housing on farm	84	11.07 (2.99)	202	11.88 (2.72)	2.21	0.03
TREVER: ever received pesticide safety training or information	124	10.87 (2.76)	156	12.13 (2.78)	–3.77	0.0002
TRYEAR: this year received pesticide safety training or information	151	10.98 (2.73)	129	12.26 (2.80)	–3.87	0.0001
PESTTOLD: told when pesticides are applied	146	10.84 (2.62)	143	12.39 (2.88)	–4.76	0.0001
PESTNAME: know the names of applied pesticides	254	11.57 (2.76)	33	11.97 (3.58)	–0.62	0.54
PESTSIGN: pesticide information posted where it can be seen	181	11.28 (2.82)	107	12.15 (2.85)	–2.51	0.01
SIGNID: restricted entry interval signs are posted	147	11.01 (2.65)	141	12.24 (2.93)	–3.73	0.0002

Table 6. Comparison of mean summed scores for Perceived Pesticide Risk (PPR) scale, by knowledge of exposure sources.

Variable source of exposure	No *n*	No Mean (SD)	Yes *n*	Yes Mean (SD)	*t*	*p*
EXWORK1: touching crops after pesticides are applied	59	13.05 (4.36)	224	14.95 (3.84)	–3.29	0.001
EXWORK2: breathing pesticides in the air	49	13.27 (4.34)	234	14.83 (3.90)	–2.49	0.01
EXWORK3: being sprayed with pesticides	50	13.26 (4.01)	232	14.86 (3.96)	–2.58	0.01
EXWORK4: swallowing sweat off face	49	13.43 (4.33)	233	14.82 (3.90)	–2.22	0.03
EXWORK5: when mixing, loading or applying pesticides	63	13.79 (4.25)	220	15.59 (3.80)	–4.25	<0.0001
EXWORK6: touching plants after pesticides have dried	101	13.44 (4.35)	182	15.18 (3.69)	–3.56	0.0004
EXWORK7: from residues on equipment	69	12.64 (4.18)	213	15.20 (3.76)	–4.78	<0.0001
EXWORK8: when riding on equipment	131	13.29 (4.27)	150	15.65 (3.45)	–5.05	<0.0001
EXHOME1: bringing pesticides home from work	70	13.53 (4.73)	213	14.89 (3.71)	–2.20	0.03
EXHOME2: bringing pesticide containers home from work	67	12.63 (4.43)	216	15.15 (3.69)	–4.66	<0.0001
EXHOME3: mix work clothes with other clothes	56	13.02 (4.84)	226	14.97 (3.68)	–2.81	0.006
EXHOME4: not changing clothes after coming home	26	12.23 (4.98)	257	14.79 (3.84)	–3.14	0.002
EXHOME5: tracking pesticides in on shoes	62	12.50 (4.40)	221	15.62 (3.72)	–4.73	<0.0001
EXHOME6: bringing unwashed food from fields	53	12.57 (4.47)	230	15.01 (3.77)	–4.11	<0.0001
EXHOME7: not bathing or showering after work	29	11.79 (4.71)	254	14.87 (3.82)	–4.01	<0.0001
EXHOME8: from residues on equipment	75	12.37 (4.20)	208	15.34 (3.65)	–5.79	<0.0001

Table 7. Comparison of mean summed scores for Perceived Pesticide Safety Control (PPC) scale, by knowledge of pesticide safety behaviors.

	No		Yes			
Safety behaviors	*n*	Mean (SD)	*n*	Mean (SD)	*t*	*p*
Ways to dress that reduce harmful effects of pesticides						
SHIRT: Wear any kind of shirt	259	11.64 (2.86)	30	11.30 (2.82)	0.62	0.54
SLEEVES: Wear shirt with long sleeves	62	10.66 (2.59)	227	11.86 (2.87)	–2.98	0.003
PANTS: Wear long pants	105	11.05 (2.91)	184	11.92 (2.78)	–2.53	0.01
SHOES: Wear shoes	110	11.06 (2.81)	179	11.52 (2.84)	–2.55	0.01
SOCKS: Wear socks	159	11.35 (2.81)	130	11.41 (2.89)	–1.67	0.10
GLOVES: Wear gloves	157	11.34 (2.90)	132	11.92 (2.77)	–1.71	0.09
HAT: Wear hat	153	11.28 (2.89)	136	11.98 (2.77)	–2.10	0.04
When should wash hands to reduce harmful effects of pesticides?						
WASHEAT: Wash before eating	47	10.55 (3.17)	242	11.46 (2.75)	–2.80	0.006
WASHSMK: Wash before smoking	209	11.56 (3.04)	80	11.74 (2.30)	–0.49	0.63
WASHBATH: Wash before going to the bathroom	183	11.71 (2.99)	106	11.43 (2.60)	0.82	0.41
When should shower to reduce harmful effects of pesticides?						
SHOWERWK: Shower immediately after work	29	10.83 (3.27)	260	11.69 (2.80)	–1.55	0.12
SHOWERCH: Shower after direct contact with chemical	237	11.75 (2.86)	52	10.96 (2.75)	1.80	0.07
Care of work clothes to reduce harmful effects of pesticides						
LAUNSEP: Launder work clothes separately	77	10.95 (2.77)	212	11.84 (2.85)	–2.38	0.02
CLEANCLO: Wear clean work clothes daily	170	11.78 (3.00)	119	11.36 (2.62)	1.22	0.22

Table 8. Correlations between Perceived Pesticide Safety Control (PPC) and pesticide safety behaviors.

Number of work days in the past week when	*n*	Peason's *r*	*p*
BEHAVEH: ate without washing hands	275	–0.23646	<0.0001
BEHAVEI: drank without washing hands	279	–0.23234	<0.0001
BEHAVEJ: smoked without washing hands[a]	88	–0.28705	0.0067
BEHAVEK: used toilet without washing hands	274	–0.15248	0.0115
BEHAVEL: wore work clothes for more than 1 day	277	–0.17708	0.0031

[a]Asked only of those who reported that they smoke.

No statistically significant associations were found between any of the pesticide exposure knowledge items and PPC. However, knowledge of pesticide safety behaviors had a strong relationship with PPC (Table 7). There was a positive association between knowledge of six ways to dress to reduce the harmful effects of pesticides, with four of these (SLEEVES, PANTS, SHOES, and HAT) having clear statistical significance, and two (SOCKS, GLOVES) having marginal statistical significance. Knowledge that "washing before you eat" and "laundering work clothes separately reduces the harmful effects of pesticides" also had a positive significant relationship with PPC.

Effects of Risk and Control on Behavior

Those with higher PPC scores stated that they used methods to protect themselves from pesticide exposure ($r = 0.24$, $p < 0.0001$, $n = 288$). Higher PPC scores were related to five specific pesticide safety behaviors that farmworkers reported that they performed (Table 8). Although the correlations were statistically significant, the coefficients ranged only from 0.15 to 0.29. These behaviors were asked in a negative format in the interview, so their correlation coefficient with PPC is negative. Stated as positive statements, those with higher PPC scores were more likely to report that, when at work, they washed their hands before eating, drinking, smoking (if they smoke), and using the toilet. They also did not wear work clothes for more than 1 day. There were eight other safety behaviors for which there were not statistically significant differences by PPC. There was little relationship between PPR and pesticide safety behaviors, with only the correlation between perceived risk and not showering after work achieving a statistically significant relationship (BEHAVEM: $r = –0.22$, $p = 0.0003$).

Discussion and Conclusions

This analysis provides important insights into how pesticide safety education must be developed to increase environmental justice for farmworkers in the United States. According to the HBM, persons must perceive themselves susceptible to risk before they will take action. This relationship is modified by self-efficacy, recognizing one's ability to control exposure to harm, and cues to action, such as knowledge and training. Our results are consistent with the HBM. They suggest that perceived control, not perceived risk, leads to action.

Our results show that providing more access to information to farmworkers (e.g., signage concerning pesticide application) increases their perceived control, but actually decreases their perceived risk of pesticide exposure. Although it is important that farmworkers maintain a healthy respect for the possible health effects of pesticide exposure, it is equally important that they use knowledge about their exposure to balance their sense of risk. Having information about when they are being exposed to pesticides seems to allow these workers to maintain a moderate sense of risk about this exposure along with higher perceived control.

Knowledge about ways to be exposed to pesticides and safety behaviors also support the HBM. Farmworkers who have greater knowledge of places at which they can be exposed to pesticides have greater perceived risk. That is, knowledge heightens their sense of susceptibility to pesticide-related outcomes. However, greater knowledge about their own behaviors that will reduce pesticide exposure is only marginally related to greater perceived risk. When behavior is examined, farmworkers do not behave more safely to reduce pesticide exposure based on their perceived susceptibility. Thus, knowing one is exposed to a health hazard is important for the perception of risk, but it is not sufficient for changing behavior.

Perceived control over pesticide safety (self-efficacy) improves when farmworkers are provided with greater information about behaviors they can take to reduce exposure. Thus, knowledge may actually be seen as power by these farmworkers. Farmworkers who know what behaviors will keep them safe from pesticides feel they have greater control over pesticide exposure. More important, farmworkers who feel they have greater control are more likely to report that they actually behave in a manner that reduces their risks of pesticide exposure. As positive as this seems, the actual correlation coefficients are quite low.

This analysis of perceived risk (susceptibility) and perceived control (self-efficacy) expands our earlier research results in which we argued that simply delivering information through educational materials and training without providing workers with a rationale for new behaviors is not enough, as knowledge did not have an effect on perceptions or sense of control (*39,43*). When farmworkers felt they did not have control over workplace safety, they did not report behaviors that reflected what they had learned about pesticide safety. Farmworkers may know that they are at risk, but they will not take action to reduce this risk when they feel that they have no control over their work situation.

This study demonstrates that pesticide safety for farmworkers is an environmental justice concern. A basic tenet of environmental justice is that local communities must have control over their environment. Pesticide training programs for farmworkers, like those developed by the U.S. Environmental Protection Agency (*44*), provide only information. For pesticide safety education to be successful—successful as measured by farmworkers behaving safely—this education must address farmworker control of pesticide safety. This control has two dimensions: content and process. The control content of pesticide safety education means that farmworkers should not only be told what they must do to reduce their exposure to pesticides, but why and how these behaviors will reduce their exposure. Behaviors that seem entirely unreasonable (e.g., wearing a long-sleeve shirt and long pants while working in the heat of an August afternoon in eastern North Carolina) become more rational when the justification for the behavior is presented (e.g., the skin is the major source of contact with pesticides, and dermal absorption is the major route of pesticides entering the body). The control process of pesticide safety education is helping farmworkers develop or implement the skills needed to ensure that pesticide safety rules are followed in the workplace. Control process includes helping farmworkers learn that they can address safety issues with their employers. Control process also includes showing farmworkers that they can solve problems of pesticide safety when their employers will not. We would expect that a greater emphasis on these aspects of self-efficacy in training farmworkers would lead to greater behavior change.

This project has several limitations. The sample was limited to one region of one state. North Carolina differs from other states in the large number of farmworkers with H2A visas. Interviews were conducted in 1999, and the regulations affecting agriculture continue to change. The project design was cross-sectional, so that it was not possible to see if perceived control or risk actually determine behavior. Further, this analysis relied on self-reports of safety behavior; differences between self-reports and actual behavior are always possible. Finally, the scales we used to measure PPR and perceived pesticide safety control have not been tested or validated beyond our study. Nonetheless, the results presented here are consistent with the HBM of behavior change, a model demonstrated to be predictive of the associations between beliefs, knowledge, control, and behavior across multiple health behaviors in numerous populations.

Although we must remain cautious in generalizing, this analysis has significance for affecting environmental justice through education. Environmental justice education programs must not be limited to information. Rather, these programs must help affected communities to gain control of the process for implementing change. The HBM, though focused on changes in behavior of individuals, suggests that environmental justice programs that gear education to self-efficacy are needed to reduce pesticide exposure among farmworkers.

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